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A computational model for mass housing design as a decision-support tool

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Abstract

Mass housing designs have become increasingly important due to the reasons of protecting urban aesthetic, providing originality and meeting the growing user demands. Accordingly, the need of having alternatives of new design approaches for these buildings has emerged. This paper focuses on the contributions of digital tools as a decision-support tool in the production of these approaches. For this purpose, an interactive plug-in which is applied in different stages of mass housing design has been developed as a computational tool by scripts of 3Ds Max software. In this paper, development processes and an implementation of this plug-in are presented.

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1. Introduction

Mass housing designs which are quietly common in the metropolitan cities have been seriously influencing on both urban aesthetic and collective or individual satisfaction of many different user groups. Until recently, these designs have been made in parallel with mass production techniques of modernism, but it is not possible to say that the satisfying results have been obtained. Today, in spite of partial changes and innovations in this approach, it is observed that its negative effects (standardization, repetition, simplification, etc.) have been still ongoing in various

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implementations. In addition, the concepts like the uniqueness, diversity and user preference have been ignored or subordinated. Thereby, the development of the design approaches which are able to present the different solutions with taking care of user preferences and requirements has become important.

Unlike its efficiency in the other fields, Mass customization couldn't be assessed adequately in mass housing design due to multiple reasons, ranging from deficiency of computer support to large numbers of different user types, differences of scale and collaboration among stakeholders. However, it has an important potential in the development of these designs in case it is benefited from technological developments and computational approaches effectively.

Mass customization contains modularity and configuration¹. When modularity refers to the products which are decomposed into their components or parts that are recombined according to the preferences, configuration defines user demands and specifications. It can also be interpreted as the installation of balancing the right of choice and standardization for user. It can be seen in different models (collaborative, transparent, adaptive customization) in architecture². Its suitable model is adaptive customization for mass housing designs which include many different users and complex relationships. In this model, users can partially make a selection or modifications like space organizations, although the production is generally standardized. However this model has not been evaluated effectively in these designs so far.

In this study a computational decision-support model which is able to present rich alternatives and to evaluate users' preferences for early stages of mass housing design is introduced³. This model is composed by integration of mass customization, the protocol of "Reflection in Action" and Cellular Automata (CA). Features of CA such as relations of neighborhood among units, a context-sensitive and bottom-up process, self-organization and a grid-based model are rather similar to the content of the mass housing designs, so it is used as a computational tool. The protocol of "Reflection in Action" provides user/ designer to be involved in the process by the way of the fragmentation of the process and feedbacks. Besides it helps to reduce the effects of CA like autonomous and uncontrolled relationships.

The computational decision-support model covers stages of site and spatial planning and facade solutions. In these stages, different CA models have been used and there have been an interactive/renewable interface. An implementation of this model is made and its results are evaluated.

2. Necessity of decision-support systems in mass housing design

Simmons⁴ states that decision-support systems (DSS) have extensive definition, but any kind of software which is used to increase the amount of the information and to organize can take part in this definition. Also, he points out that many computational methods from simple electronic sheets to a word processor document can be evaluated in the scope of DSS when it is taken to extreme. These systems are usually viewed as making-decision processes for non-programmed decision problems.

Basic needs of a design-decision support system are similar to Simon's stages of decision-making process. These ones are also Intelligence, Design, Choice and Review activities. Design activity which is the methods needed for generating and analyzing sets of alternatives is the most important one among them. Generally, this activity takes place in four stages which are representing, structuring, simulating and viewing.

Representing includes methods and tools for encoding a set of decision variables, a set of the constraints among design variables and a set of metrics for calculation.

Structuring includes methods and tools for reasoning interconnected variables, providing information about the relationships and manipulating according to conditions.

Simulating includes methods and tools for identifying feasible combinations of decision variables and computations of properties of decision outcomes.

Viewing includes methods and tools for presentation of decision-support information obtained from other stages in human-understandable format.

Preferable features of decision-support systems in architectural design implementations can be listed as follow⁵:

- Being used in semi-structured or unstructured decisions
- Helping decision-maker to make a decision instead of taking his/her place.
- Supporting all stages of decision-making process

- Being user-controlled
- Using Model
- Being user-interactive
- Providing support for multiple independent or dependent decisions
- Providing support of making decision based on individual and group
- Providing ease and flexibility of implementation

As a result, decision-support systems are useful for ill-defined problems like design. Accordingly, decision-support tools which have these features are required significantly in the large-scale design processes such as mass housing designs which necessitate optimum solution due to its complex relationships (site planning, space planning, user preferences, legal limitations etc...). It is thought that these tools can be evaluated flexibly in different forms in different stages of a design process.

3. Cellular automata and its implementations

Cellular Automata (CA) is one of the most common generative design tools like Shape grammars, L-systems, Genetic algorithms and Agent based models. It comprises the cells which represent one of the defined states related to the set of rules which operates according to the state of neighbor cells in certain time and in a grid layout⁶. It has basic properties like autonomy, heterogeneous, universal order/self-organization, self-maintenance, adaptation and hierarchy⁷. It can be represented as different models like classic models (Wolfram's one dimensional, Conway's and Ulam's two and three dimensional samples) and advanced models adapted to different disciplines (physique, biology, urbanism etc...).

In architecture, potentials of CA have been researched by the implementations of different designers like Frazer⁸, Coates⁹, Krawczyk^{10,11}, Clark and Anzalone¹², Herr¹³, Devetakovic and his team¹⁴ etc. These implementations have been usually made by using rule sets of existing classic systems like Conway's Game of life and interpreting their results as an architectural form. However Herr's work called "Algogram" differs from the others with its features of being a sample of advanced preliminary design stage for architecture and using a model of CA which is adapted to architectural design. In her work, she demonstrated that CA could be evaluated in different ways both formally and conceptually for different stages of the design studies.

4. A decision-support tool for mass housing design

Mass Housing Designs are typically evaluated both in urban context and in building scale. In urban context, decisions of site plan where forms of housing building are designed by concepts like aesthetics, transportation, common places, and legal restrictions are interpreted. In building scale, there are space organizations where individual needs of users are met and relationships between users are established, and façade designs for building aesthetics. The suggestive model has been developed for simulation of these processes.

As a computational tool, CA is evaluated in the proposed model because structures of CA and mass housing designs are similar both logically and formally. In other words, characteristics of CA like neighborhoods, context-sensitivity and grid based design; self-organization, etc. are compatible with relations of housing block placements, spatial organizations and façade organizations in these designs. This is also illustrated in the model. Additionally, CA's ease of use and simplicity in terms of its structural properties is a reason of preference for this model. For all implementations, scripts and interface of 3Ds Max software have been utilized.

The model has been designed in the scope of the protocol of Schon's "Reflection in Action". In this protocol, a design process is fragmented with frame steps which can be interpreted, developed, or reconfigured by a designer¹⁵. Similarly, stages of site and space planning and façade designs refer to these steps in the model. Accordingly, rules of CA have been also developed separately for each stage. Through feedbacks, these rules can be renewed in accordance with states of results in the stages if it is necessary. However the model is basically operated by "Generate and Test".

4.1. Decisions of site planning

In this stage, placements of discrete housing blocks which have a defined floor area and whose height can be changeable in the site plan are envisaged in the framework of plot information (plot layouts, legislative limitations, rates of public spaces and min/max heights of building masses) which is determined by the means of developed interface. In these placements, support of CA is based on neighborhood relations depending on their position among the created housing blocks. Future of each new housing block and existing housing blocks is decided according to state of their proximity to each other, which is defined by legislative limitations or shadow cone. All housing blocks are surviving in case the state of their proximity is acceptable. Otherwise, a choice for removing (death) is made among these blocks with defined rules (Figure 1).

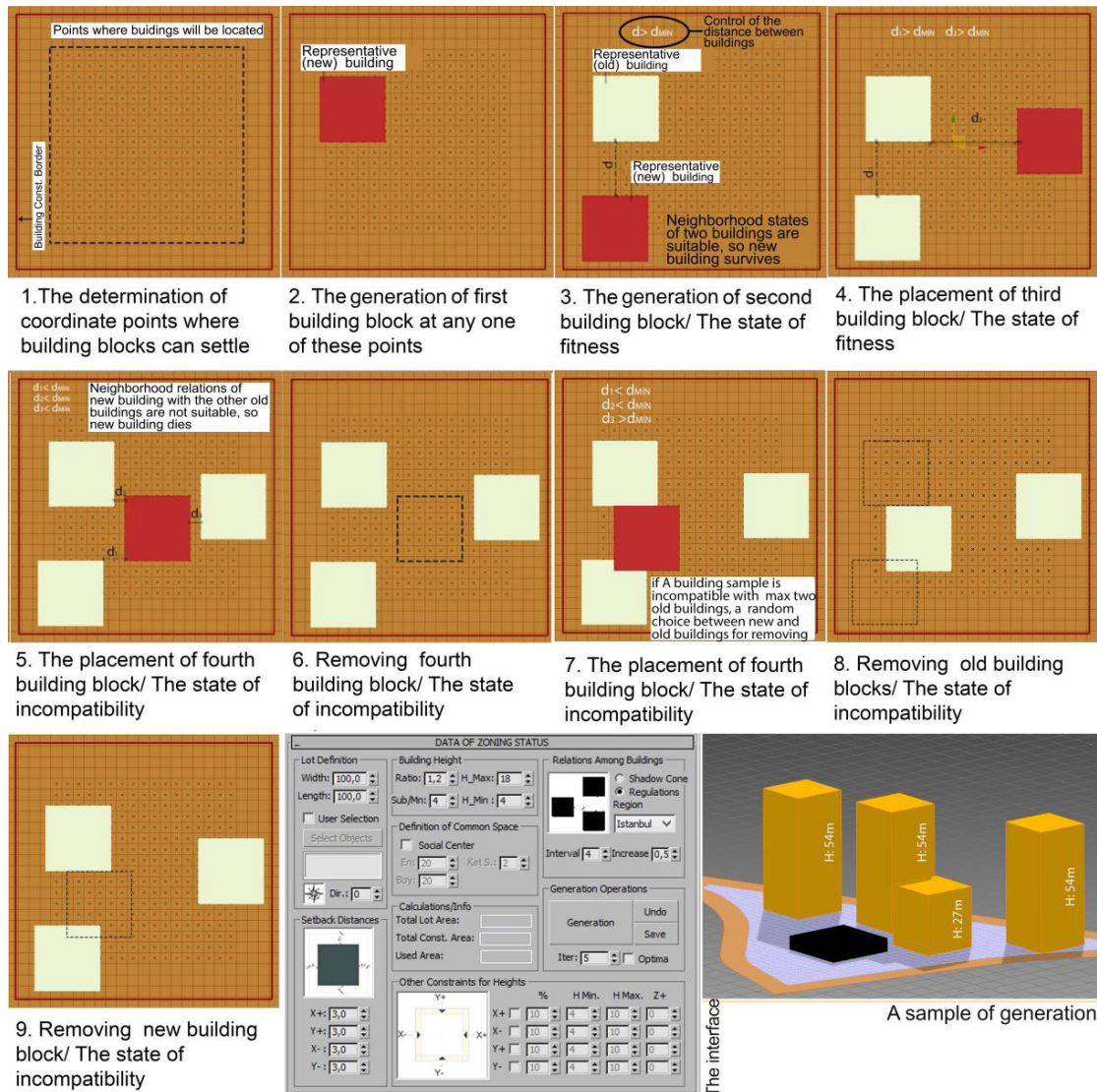


Fig. 1. Implementation process and interface of site planning.

A generation process starts with random placement of a housing block which has minimum height in a site. When total area of the existing blocks in the site is equal to the limit of total construction area, the process is completed and the results are evaluated. In the model, user interventions are partially allowed by the way of changing block heights for the specific regions of the chosen site.

4.2. Decisions of space planning

In this stage, solutions of space planning are realized separately for the sample of each building which is generated in the decisions of site planning. These solutions are made by user preferences for each floor of a selected building sample. Users prefer one of different housing types which are grouped by examples of one (1+1), two (2+1), three bedrooms (3+1) and more (double flat). According to amount of these preferences, sharing area for their placements is made among these housing types in the floor plan. If the criteria are provided, creation of housing types is decided and generation process for spatial units is initiated.

The proposed model for solutions of space planning is open floor plan which has a service core of building whose position is constant throughout all the floors and changeable spatial units around it. Depending on dimensions of the building samples, it is a 24*24m grid plane which is subdivided by 8*8m and 4*4m smaller grids at each floor. Service core covers an area of 8*8m in the center of the plane. Remaining spaces are shared among selected housing types for placement of spatial units (Figure 2).

Generation process starts with the random placements of “Entrance Hall” units in the shared housing type regions and these units trigger creation of other spatial units (kitchen, bathroom, bedroom etc...) in the framework of neighborhood rules among spatial units. Other spatial units follow a similar step and affect generation, transformation or deletion of further units. This process continues until reaching the criteria of selected housing types and filling in the blanks of the floor plan. During the process, the spatial units which cannot provide the criteria of selected housing types are deleted. The empty units which are existed by removing the cells are re-evaluated in the generation of the others or new housing types. When the process is completed, the results are interpreted by designer/user. If the results are acceptable, solution of another floor plan is passed. Otherwise, this process is restarted (Figure 3).

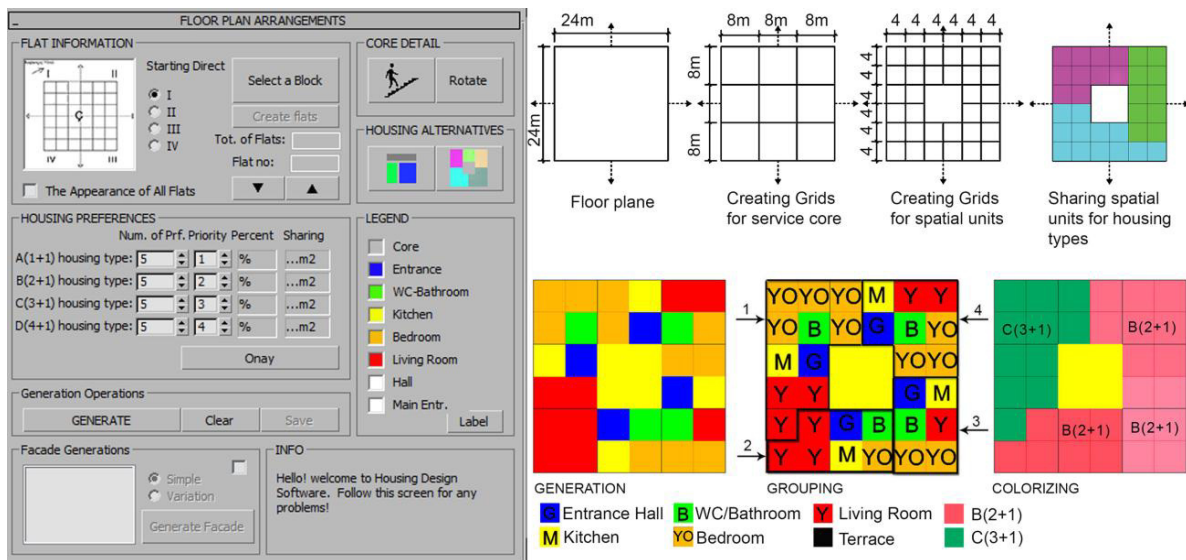


Fig. 2. (a) Interface of space planning; (b) preparation of a floor plane for generation; (c) a solution sample for a floor plane.

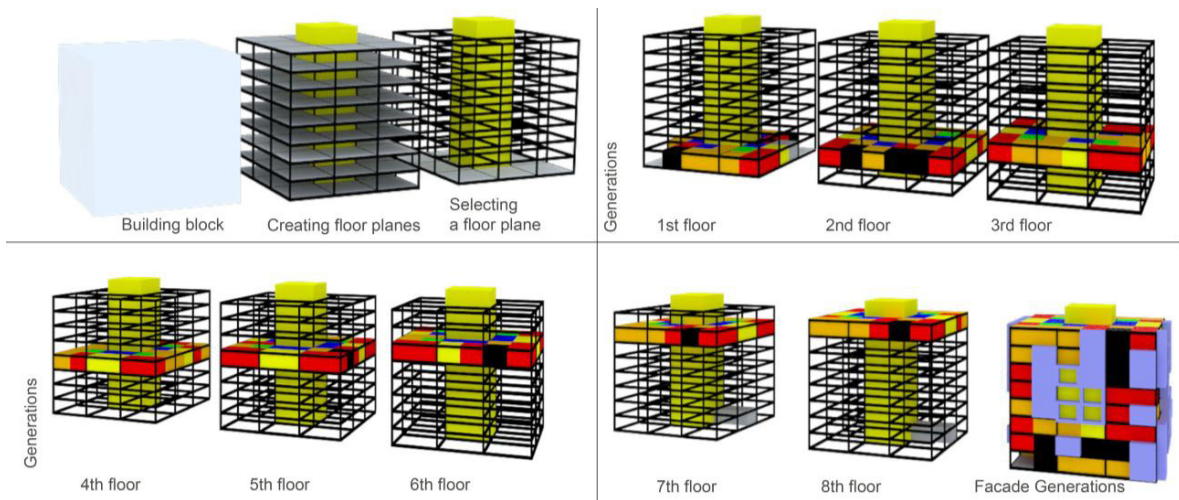


Fig. 3. Implementation stages of space planning for a housing block.

In spatial planning stage, a lot of neighborhood rules among spatial units which are similar to Conway's Game of Life and consist of the concepts like surviving, birth, death, transformation, etc. have been developed according to their dimensional states in a housing type and their relations with each other. A few samples of these rules spatial units can be given as follow:

- "Entrance Hall" units which are generated at starting are placed on the floor plan in case they have a neighborhood with other spatial units except "Entrance Hall" units. Otherwise, these units are evaluated as "death" and removed (Figure 4).
- "Kitchen" units are usually placed opposite to "Entrance Hall" units. In some cases, for an example, these units can be created near to right or left of "Entrance Hall" units for some (1+1) housing types.
- If there are two void units at right or left of a "Kitchen" unit, which doesn't have a neighborhood with the service core, according to its position and these are not neighbor with "Living room" units, new "Living room" units are created on these two units. Also, when there are void units on both sides of a "Kitchen" units, there is a prioritization among them. If a void unit which is neighbor with "Kitchen" unit doesn't have a neighborhood with a "Bathroom/WC" unit, this unit and the other neighbor void unit are primarily preferred for creation of "Living room".
- "Bathroom/WC" units are defined as a single-cell for same housing types. If they are more than one, the operation of removing or changing the function is applied for them.
- If a "Bedroom" or a "Living room" unit is neighbor with service core, a "Terrace" unit or a similar functional ("Bedroom" or "Living room") unit opposite of it according to its state of neighborhood with service core.
- If a "Living room" unit have neighborhoods with more than two "Living room" cells, they are evaluated as "death" and defined as a "Terrace" space

Rather than replacing a designer, the model plays a role as a supportive tool with its alternatives in design works and the contributions of "Reflection in Action" approach. The generated plans in the model are primitive samples which can be detailed, developed or interpreted by a designer later. Similarly, as stated before, the neighborhood rules and the relationships can be also changed, multiplied and removed according to designers' criteria and principles. Furthermore, the structural configuration of the model allows flexibility for optional spatial changes. With aim of preventing the problems which may occur due to spatial differences among the floors of the chosen block, mechanic service elements like plumbing installations and shafts are considered to be located around the service core. Finally, the dimensions of the service core are determined to have circulation areas, elevators, and general and fire stairs.

4.4. Implementation of the model

The proposed model has been experienced with an implementation in the region of Karabuk-Yenişehir in Turkey. In the implementation, a building site which was unified by two separate parcels was chosen and defined by user on the interface. Legislative regulations of the region were evaluated. Samples of site plan for housing blocks were generated by using different parameters direction of landscape, elevation difference, defining social area, determining special building heights for special areas etc. After each generation, different orientations of the placement were obtained (Figure 6).

In the second stage, after one of the generated site plan samples was decided, one of the housing blocks, which was located on this site, was chosen for space planning. User scenarios were envisaged for all floors of the chosen block and defined separately on the interface of the proposed model. According to this envisaging, users preferred to only A (1+1) housing type in ground and first floor plans; A (1+1), B (2+1) and C (3+1) housing types in second and third floor plans; only B (2+1) housing type in fourth and fifth floor plans; and only C (3+1) housing type in sixth and seventh floor plans. In this framework, various alternatives were generated for each floor by using small parameter changes like starting direction for generation and prioritization for housing types. When very few of the generated plan alternatives were resulted negatively, they were usually useful and developable. Examples of these alternatives are shown in Figure 7.

In the implementation, due to the state of re-evaluation of the remaining empty cells during the process, non-preferred housing types were emerged in the solutions of some floor plans. However, this condition contributed to increase the alternatives significantly.

Finally, after completion of floor plan solutions, samples of facade orientations were generated by means of the interface (Figure 8). These generations provided to have variations in third dimension and to make dimensional differences among similar housing types in spatial planning. As before, at each generation in this stage, for each block façade different orientations were also obtained. Accordingly the opportunity of having and evaluating more alternatives emerged for a designer.

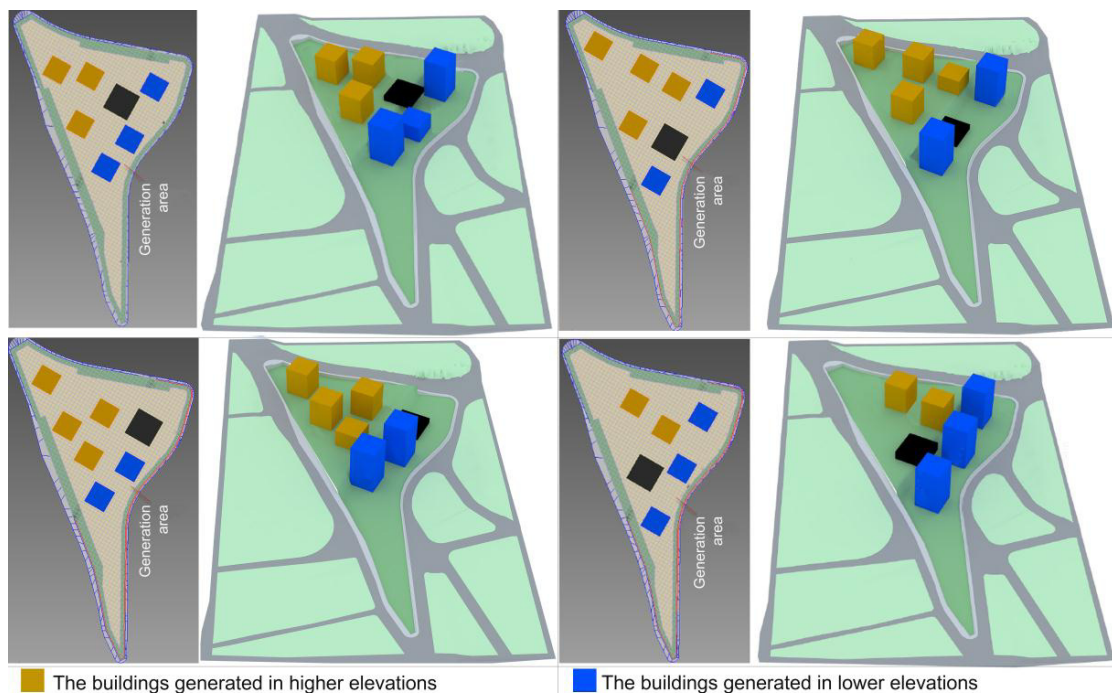


Fig. 6. Site plan implementations made in Karabuk-Yenişehir.

5. Result and suggestions

Existing mass housing design approaches which require users' satisfaction individually and collectively have been insufficient so far. It is difficult and exhaustive to configure, manage and produce a lot of design alternatives for many different users by the methods of traditional methods. However, timing, flexibility and diversity are important needs for these designs. For this, a solution is support of computational tools in well-organized designs. In this work, the proposed model has demonstrated it by experiences of its development process and a sample implementation. Results and suggestions obtained from the model are as follows:

- When the model which is suitable for design problems is designed and organized, it presents opportunities of alternatives. Defining rules and planning the process can be restrictive and time-consuming, but processes of organizing the rules with feedbacks both extend designers' workspaces and support them with unique alternatives. The results of the implementation proved it. During the process, according to the results, the model was re-organized with new ideas.
- When mutual relations between human-designer and generative tools are well- built and evaluated positively, results of the design processes are much better and more useful. Additionally it is considered that these tools make much more contributions to users and Schön's "Reflection in Action" approach is still valid for design implementations.
- CA models have a potential to affect decision-making processes positively and to be used in different stages (site organizations, spatial relations, circulation, design of building envelope etc...) of an integrated design process which have interactive well-defined, modular and complex structures and properties.
- It has seen that role of the decision-making tools is very important and necessary for especially design studies which include many different users and relationships in terms of saving time, managing different requirements and solutions effectively and getting more optimum results. Even though it is in different forms, it should be evaluated in these implementations.
- Rules, relationships and configurations in the suggestive model have generic and flexible properties and they can be used with different approaches for different design processes.

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